THE INTERINDUSTRY RELATIONS STUDY AND ITS APPLICATIONS

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Theory of the interindustry study

It is common knowledge that the various parts of the American economy are closely related -- that a change in price or output of one industry will have repercussions in many others. The interindustry relations study is based on this fact plus the additional observation that the manner in which different segments of the economy are related tends to be predictable. Although the basic structure of the economy changes in response to technological progress, to redistributions of wealth, and to altered tastes of consumers, these changes are usually gradual; for instance, the amount of steel and rubber needed to make an automobile, or the tons of pulpwood required for manufacture of a ton of paper change but slowly.

Francois Quesnay was the first economist to explore systematically the mutual interdependence of all sectors in the economy. Writing in France during the mid-eighteenth century, Quesnay had a considerable influence on the development of economic thought, and his "Tableau Economique" which attempted to show the structure of the French economy influenced many later-day economic concepts.

Nearly a century later Leon Walras, another Frenchman, formulated a set of mathematical equations expressing the conditions necessary for "general equilibrium" of the economy. These equations showed how an initial impulse brought about by a change in output or price of one product would be transmitted throughout the entire system, affecting all other outputs or prices.

It was not, however, until our own day that there was a serious effort to make the general equilibrium theory operational by fitting the necessary quantitative data into a comprehensive framework. Professor Wassily Leontief began such a project at Harvard more than 20 years ago. Using census data primarily, he constructed "input-output" tables showing the structure of American economy in 1919, 1929, and 1939. More recently the Bureau of Labor Statistics and various other agencies of the Federal Government have been cooperating in a detailed analysis of the structure of the American economy for 1947 and 1950.

For purposes of these studies the economy is viewed as being divided into several relatively homogeneous industries or sectors. Each sector buys from and sells to the others. Thus the motor vehicle sector buys inputs from the steel industry, from the rubber industry, from the machine tool industry, from the household sector (which supplies labor), and from others. These inputs are combined according to relatively fixed technological processes into cars and trucks and sold to purchasers who may be "households," other industries requiring motor vehicles, foreign buyers, and the like.

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The quantities and kinds of inputs required by each industry per unit of its output are predictable, at least for outputs similar to those experienced in the past. This functional relationship of inputs to outputs in the industrial process constitutes the structure of the economy.

Of course, it is possible to regard the inputs and outputs of all sectors of the economy, including ultimate consumers, as being functionally related. However, the relationship between the incomes of final consumers and their purchases is much less predictable than the relationship between inputs and outputs of intermediate manufacturing, processing and service industries. Hence it is useful to regard the purchases of ultimate consumers as being "autonomous" and constituting the "final demand" for each industry's output. The size and nature of this final demand is determined in part by forces generated outside of the economic system. Purchases by households, by the military, for foreign trade, by governments, for construction, for plant expansion, and the like, constitute the final demand for the output of each industry. The sum of these final demands is roughly equivalent to the gross national product.

The structural relationships in each industry can be expressed by a series of equations. A separate equation for each sector shows output of that industry as a function of it's inputs. All of the equations together make up a matrix that describes the structure of the entire economy. By solving these equations simultaneously the ramifications throughout the economy of a change in output, price, or structure in any sector are readily apparent. For instance, the economic effects of a change in the final demand for cars or of a change in the amounts and kinds of inputs required to manufacture a car can be seen.

The discussion above has been chiefly in terms of quantities of inputs and outputs. The price structure can be viewed in a parallel manner to the input structure, the relationship of prices and costs being regarded as stable. In practical application, however, price and quantity elements are combined so that quantities of inputs and outputs are expressed in physical terms weighted by dollar value.

Relation to other methods of economic analysis

A comprehensive conceptual framework such as the input-output system helps us to understand economic relationships better and to bring all available relevant data to bear more effectively on problems. However, it cannot be expected that this or any other theory will enable us to predict the actual course of economic events, since a great many factors other than those considered in the equations help to determine what will happen. An adequate theory, nevertheless, will assist in making meaningful conditional statements so that an analyst can say "if these conditions hold then such and such will result." Other kinds of economic prediction are beyond the scope of any analytical methodology.

The fact that a theory does not enable us to forecast future happenings does not mean that it is not a significant advance in thinking and understanding. Harvey's theory of the circulation of the blood was of little help in predicting how long a person could be expected to live, but it did clarify thinking so that many great advances in medicine became possible.

Theory and factual data.--One function of an adequate theory should be to point out what empirical data are needed and to provide the framework for organizing and explaining these data. A theory that does not lead to hypotheses that can be checked against the facts is seldom of much value. A great limitation of classical economics has been that they have not produced many operational hypotheses that could be tested through actual observations. The input-output approach is a step towards remedying this situation in that it provides a framework for using great masses of available data to examine the validity of many cherished postulates of economics. (8) 1/

Methods for economic analysis.--Economists have developed several methods for analyzing various types of economic problems. All are useful on occasion. The input-output approach is only one more tool in the practicing analyst's kit.

The analytical tool with which everyone is probably familiar is the supply and demand curve concept. This method of analysis is a partial one in that it assumes "all other things to be equal" while changes in a single industry are examined. It results in static analyses because a demand or supply schedule depicts a situation during one moment of time only; changes over time have to be accounted for by postulating "shifts" and "changes in shape" of the schedules.

Partial analysis of the supply-and-demand-curve kind can be made more dynamic by using the shape of the schedules to explain the path of prices and outputs over time. The cobweb theorem explaining the famous "corn hog cycle" follows this partial but dynamic approach. (2)

A third type of analysis is that represented by the input-output approach just described. This method of analysis is general since all elements of the economy are simultaneously considered. The approach is static, however, because explanations of changes of input-output flows over time are not explicitly "built into" the system. (6)

It is feasible to construct an input-output model that is also dynamic. To do this it is necessary to relate functionally the capacity and capital stocks of each industry to the flows of its inputs and outputs and to introduce time as a variable in the equations. Both theoretical and empirical work is being done on such a model at the present time. (9)

The analytical method known as linear programming resembles the input-output approach in many ways. Linear programming makes it possible to determine the production processes (activities) which are most likely to maximize or minimize certain values when there are a great many variables

1/ Parenthetical numbers refer to list of References, p. 13.

involved. For instance, where there are certain outputs of various products required for the defense program the problem might be to choose the production processes for achieving these outputs that will result in the minimum use of certain strategic raw materials; or alternatively the problem might be one of obtaining maximum outputs from given limited quantities of these scarce resources. The application of activity analysis to economic problems is still in its experimental stages, but this tool promises to become an important one in the future. (5)

The analysis of activities need not be restricted to problems of simply maximizing or minimizing certain values. The recently developed theory of games provides techniques for arriving at the most advantageous solution in a game of strategy, and this may be neither a simple maximum nor a minimum position. Several economic problems bear considerable resemblance to those of players in games of strategy, like chess or poker. Capitalizing further on this resemblance promises to be another helpful development in economic analysis. (5)

The Bureau of Labor Statistics interindustry relations project

As early as 1941 a small group of economists in the Bureau of Labor Statistics became interested in Professor Leontief's work. They saw in the input-output approach a practical means of obtaining additional insights to complicated employment, wage, and industrial activity problems. In the past, problems simultaneously affecting many sectors of the economy had usually eluded quantitative analysis. Following World War II, the BLS used Leontief's approach experimentally in analyzing possible employment patterns for 1950. The results were so good that BLS economists were encouraged to go ahead and expand interindustry research.

The numerous economic complications caused by wartime mobilization and controls gave further stimulus to the interindustry relationship investigations. In fact, some kind of economy-wide tool of analysis like the input-output system seemed to be the only way to get at the large secondary effects often resulting from the expansion of certain industries and restrictions on others. Faced with the prospect of industrial mobilization in event of war the Air Force became interested in the input-output technique; it offered a means of gaging the effects on the economy of various military procurement programs and of judging their feasibility. Substantial Defense Department funds were made available, enabling the BLS, a few other agencies and several universities to work with the Air Force on interindustry data for use in mobilization problems. The Bureau of the Budget took over the coordinating function in this research. In addition to work done by the BLS and Air Force, interindustry research projects were undertaken by the Department of Commerce and the Bureau of Mines. Practically all Government agencies cooperated in some degree.

A major task in all this accelerated research was to assemble data showing in detail the flow of goods and services throughout the economy during some base year; 1947 was selected since the most recent census of manufactures was made for that year. Data were assembled showing inputs and outputs from some 450 sectors of the economy. These data were recorded on punch cards; to publish a 450-sector table could require nearly 200,000 separate entries and take up hundreds of printed pages.

The BLS published first a 50-sector summary input-output table and later a 200-sector table. These were arrived at by aggregating the more detailed 450-sector punch card data. While some detail is lost through aggregation, the 200-sector table gives a fairly complete picture of the structure of the economy in 1947.

Professor Leontief explained input-output economics and summarized the 1947 data in a popular article that appeared in the SCIENTIFIC AMERICAN in October 1951 (7). The 50-sector tables along with a comprehensive explanation were published in the REVIEW OF ECONOMIC STATISTICS, May 1952, in an article by W. D. Evans and Marvin Hoffenberg (3). The 200-sector tables, printed on large sheets, are available from the Bureau of Labor Statistics (14) along with explanatory material. Copies of these materials are in the Forest Service files.

The various sectors shown in these tables represent a compromise between a classification by product and a grouping by industries. If each industry produced only one product there would be no problem in grouping them into different sectors, but this is seldom the case. Where one industry produced several products, all but the primary product are shown in the tables as being transferred as an output from the industry of origin to an input of the industry where that product is primary. Thus if the sawmill industry produced some surplus electric power for sale it would appear in the input-output table first as a transfer to the electric industry and then as a sale to the consumer.

Where there was no actual industry primarily producing a specialized product, dummy industries were sometimes set up so that the input pattern of the producing industry would not be distorted. For instance, dummy industries are shown in the 200-sector tables as producing hides and scrap metal.

Trade, transportation, merchandizing and the like are shown as separate sectors. These functions call for unique patterns of inputs and outputs even though they may be organized institutionally as part of a manufacturing or processing industry.

All entries in the tables are in terms of "purchaser's values." Conceivably physical units of tons, cords, etc., could have been entered. However, both finding the original data and subsequent mathematical manipulations are made easier by using a common-value denominator. Each value entry can be thought of as a physical quantity weighted by 1947 price indices.

Interpreting the 1947 input-output tables

It would help the reader in following the remainder of this explanation if he would refer to the three 50-sector tables (Nos. 4, 5, and 6) appearing in the article by Evans and Hoffenberg (3).

How to read table 4.--The different sectors or industries are listed in order from top to bottom and again from left to right. Each row of table 4 (across the page from left to right) shows how the total output of that sector was distributed among the sectors listed on the top of the page. The entries from top to bottom in each column show the origin of each of the inputs used by the industry listed at the top of the column. Sectors 45 through 50 of the table constitute the final demand. This input-output table summarizes the transfers of goods and services that took place during 1947. For instance, the furniture and fixtures industries (sector 7) bought $385 million of its inputs from the lumber and wood products industries (sector 6), $1,063 million (labor) from households, etc. At the same time the furniture industry sold $102 million to the radio and television industry (sector 24) and $1,459 million to consumers in households (sector 50), etc.

Table 5 closely resembles table 4. It shows for each sector listed on the top of the page the dollars worth of inputs required directly from the industry listed on the left to produce one dollar's worth of product. These ratios of input per unit of output are the 1947 input coefficients.

Input coefficients not shown for all sectors.--One will observe that in table 5 input coefficients are not shown for sectors 46-50. This is because the inputs and outputs of these sectors representing ultimate consumers cannot be regarded as being functionally related in any simple manner. The input-output relationships of the raw-material-producing and intermediate-processing sectors (sectors 1-45) have a stable technological basis; an increase in output will generally call for a proportionate increase in inputs. The input requirements of the final demand sectors, however, are not determined solely by this technological relationship of inputs to output. The requirements for various goods and services of governments of "household" consumers, of foreign trade, of construction, and of the military, for instance, are in large measure determined by external "autonomous" factors. As explained above these sectors can be thought of as constituting the final demands for the products of the economy.

No coefficients are shown for 3 of the dummy industries appearing in the large 200-sector tables for another reason -- their input patterns have no real technological counterparts. The production of hides, for instance, is solely a by-product of cattle production. Thus the input structure of the "dummy" hide industry has no analytical significance. In the 50-sector tables, dummy industries are not shown separately.

Fixed input coefficients.--When the input-output method is used analytically it is usually assumed that the input coefficients remain fixed for purposes of the problem at hand. In other words, an increase or

decrease in the output of any sector will call for a proportional increase or decrease of all that sector's inputs. In mathematical terms, the input-output equations are linear and homogeneous.

As everyone knows, the proportion of each input to total output of an industry is not necessarily fixed. The "law" of diminishing returns is in contradiction to this assumption. Nonetheless, to assume fixed input coefficients for short-term analyses of large industries is a good approximation of the facts. The engineering "recipes" for producing most products cannot be changed easily. If they are changed, it usually means investments in new processes, tools, and the like, that take time to accomplish on a large scale. Fixed coefficients are usually more realistic, however, the shorter the time period involved and the nearer output remains to the base period level.

In the long run, structural change is a dominant characteristic of the economy. If this were not so we might still find over three-fourths of the labor force engaged in growing food. But changes tend to be gradual for any large sector of the economy; and the direction and speed of technical change can often be foreseen.

<u>Table 6--direct and indirect requirements</u>.--Table 6 shows the quantities of outputs and inputs that would be required either directly or indirectly as a result of increasing the final demand of any sector's output by $1. The table shows how economic activity is generated throughout the whole economy whenever the output of a single sector is increased. The table is sometimes spoken of mathematically as the "inverse matrix" and was arrived at through solving all of the input-output equations in the system simultaneously.

The importance of indirect requirements is shown in the following example. Table 5 indicates that the radio industry requires only 0.6 cents of additional production directly from the lumber and wood products sector per additional dollar's worth of radios sold to consumers. Table 6, however, reveals that the actual increase in lumber production required both indirectly and directly by delivery of an additional dollar's worth of radios to consumers would be 3.2 cents. The indirect lumber requirements in this case were more than five times as great as the direct. This was largely because an increase in radio production calls for a greater output of cabinets produced by the furniture industry, which in turn purchases most of its raw material inputs from the lumber and wood products sector.

Limitations of the interindustry analysis

We have mentioned several assumptions inherent in the 1947 interindustry model. They can be examined under three main headings. The analyst should make certain that he understands these underlying elements before using the data. <u>First</u>, the tables assume a fixed input structure.

Changes in the proportions of each input required per unit of output are not allowed for. In addition, no allowance is made for the introduction of new industries or for other changes in production patterns. Second, a unique demand structure is given implicitly by the table. Changes in final demand associated with different social conditions and income levels or altered tastes have to be explicitly taken into account; these adjustments are not automatic within the system. Third, the factor payment structure is also fixed. Relative prices and wage rates are assumed to remain the same. Changes in the distribution of wealth, power, and income on which the factor payment structure is based would alter this pattern.

The analyst can introduce structural changes into any of these three elements. But if this is not done he must remember that he is assuming their structure remains the same. These assumptions do not invalidate the use of interindustry analysis; the same set of assumptions plus others have to be made when using any other analytical method now practicable. A truly "dynamic" input-output model could, however, make automatic adjustments for some types of the changes mentioned.

Adequacy of the basic data.--Of course, the input-output method cannot give results which are better than the quality of the data used. Many critics have questioned whether the statistics in the 1947 table are reliable enough to be a good guide to the real structure of the economy.

The answer to this is that the data are about as good as any available and give us the best description of the economy there is. For instance, the data on inputs and outputs of the sawmill and planing mill sector were painstakingly assembled using Census, Forest Service, and industry supplied figures. Conflicts were eliminated insofar as possible. The data were cross-checked in several ways since not only do the inputs of each sector have to add up to that sector's total output, but they have to be consistent as a component part of the total output of each sector that supplied them and this output in turn must be consistent with that sector's inputs.

In several places the interindustry figures appear to conflict with Forest Service figures. Upon checking into these cases it became apparent that the discrepancies were almost always due to differences in definition and classification, not to a conflict in source materials. The input of timber products of the railroads, for example, is from the construction industry instead of directly from the sawmill industry.

Computational difficulties.--The difficulties of handling numerous equations simultaneously has often been cited as a serious objection to use of the input-output method. This objection is not usually well founded. The mechanics of solving the numerous equations by the use of large computing machines are relatively simple. Climatologists and engineers have worked with mathematical systems of similar complexity as a matter of routine for some time now.

This is not to say that anyone can set up a problem with his own data and set of assumptions and get it solved easily. Manipulating the entire set of equations is inevitably cumbersome and expensive; the general analyst wishing to use input-output methods and data will have to make use of the published tables already described. If his problem involves different structural assumptions and basic data, he will have to make allowances where possible or else have the facilities for undertaking an expensive computational job.

The input-output methods and data will give insights to a host of small and specialized problems even though it will seldom pay to focus the whole input-output analytical machine on a single minor question. By using the 1947 tables showing input coefficients and direct and indirect requirements anyone can compute the generated activity resulting from a revised final bill of goods. All that is needed to do this is sufficient judgment, patience, and a desk calculator.

Areas of application for the 1947 interindustry data

In a paper delivered before the 1952 Conference on Income and Wealth, Evans and Hoffenberg (4) discuss application of input-output analysis to various problems. Since its possible application to Forest Service problems is our main purpose for looking into the interindustry project, we will summarize some of their observations here.

Probably the most general and simplest application is in pointing up the numerous factors that one should take account of in any economic analysis. A better understanding of the complex nature of an industrial economy will almost certainly result from a study of the input-output tables. Use of the table brings out clearly the heroic assumptions that are made implicitly when using simpler methods of analysis. Also, the conditions necessary for consistent answers can be ascertained.

Production response to altered demand.--But there are also many specific areas of application. The simplest is in answering the question of what production will be required throughout the economy to meet an increase in demand for the product of any one sector. This means finding both direct and indirect effects of the change in demand. The question can be answered by referring to table 6 (3). Indirect demands may be very large compared to the direct additional requirements. For example, using 1947 data the total requirements for electric power necessary to increase production in the motor vehicle sector would be more than five times the additional direct purchases of power by the motor vehicle sector.

Factor payments.--The analysis of direct and indirect requirements resulting from a change in final demand can be extended to estimate the total additional payments to the various factors of production. For example, assuming a fixed processing, demand and factor payment structure, one can determine the distribution among different sectors of a million dollars' worth of new final demand for agricultural products.

Induced employment.--One of the most obvious uses of the interindustry system is in determining the relation of production requirements to employment. In fact, it is possible to construct a table showing the direct and indirect requirements for additional employment resulting from an additional million dollars of final demand from any sector in the same way that table 3 showed the direct and indirect requirements for all products.

Resource requirements.--Similarly, the method and data can be used to analyze the additional requirements for any basic resource if final demand in one or several sectors is increased. Applications for estimating timber requirements in the short run are obvious. The longer run impact of an expanding economy on resource use is much more difficult to evaluate and such estimates require extensive use of collateral data and analyses. Valuable insights may result, nonetheless, through use of the interindustry data.

Price and market analyses.--Theoretically, changes in prices resulting from a change in wages or a change in price of some commodity can be analyzed in the same way that changes in the quantities of inputs and outputs resulting from a change in input coefficients are analyzed. Actually, there probably is a great deal of stickiness and unpredictabl irregularity in the price system; price impulses tend to be transmitted with less orderliness than production changes. But additional insight about results to be expected from long run changes in price relationships undoubtedly can be obtained through using the interindustry model.

The interindustry tables should also be of help in making market analyses. The marketing structure of any industry is laid out before the analyst of an input-output table since it shows both the immediate and ultimate distribution of all goods produced. The means are thus provided for relating quantitatively the demand for end products, like paper, with markets for industrial goods and raw materials.

Regional analysis.--Regional and inter-regional quantitative economic analyses have always been unsatisfactory. Secondary benefits and costs accruing to a region as a result of a development program cannot be measured by traditional methods. Also, the regional impact of a change in national final demands is difficult to assess. The interindustry method provides a tool for approaching these problems. It may be a long time before adequate data are available for meaningful regional analyses But the interindustry method makes such studies at least feasible; other and more traditional methods could not make full use of regional data even if available.

Forecasting.--Possible use of interindustry methods in forecasting has attracted considerable attention. As already pointed out, however, forecasting in the sense of predicting the future is beyond the scope of any economic method. All that the interindustry system can do is help in making more accurate conditional statements about future production and distribution of goods and services. A recent study by the Bureau of

Mines (1) illustrates how the 1947 data might be used in making long-range conditional forecasts.

If by other methods one can predict the processing structure of the economy, the demand structure, the factor payment structure, and the level of economic activity at some future date then the interindustry method allows an accurate prediction of actual requirements for any resource. But the predictions will be no better than the basic premises the analyst makes about the future shape and size of the economy.

One may well question what use the method has at all in forecasting. The answer is one of alternatives. The main alternatives are to use pure judgment or to extend past trends. There is no need to point out here the theoretical objections to extending regression analyses beyond the range of observations. If past conditions do not apply in the future then the estimating equations become useless for forecasting.

The interindustry methods makes three definite contributions to forecasting. (a) It helps the analyst to formulate and use explicit and consistent assumptions about the basic structure of the economy. (b) It enables him to make a logical and self-consistent deduction of requirements based on these assumptions. (c) It provides the widest possible statistical base for drawing any quantitative inferences.

Testing the interindustry model's forecasts.--The applicability of the input-output method for forecasting is discussed by Professor Leontief (6). In an essay on structural change, Leontief "forecasts" 1939 outputs and inputs using 1929 input coefficients but using actual 1939 final demands. He does the same kind of forecasting for 1929 using 1929 final demands but the 1919 input structure. The results are most interesting. Despite problems arising from noncomparability of some of the data between various decades, and index number problems that arise in expressing all outputs in base-year dollars, the predictions made in this way were surprisingly good; they indicated that structural changes in production were not so overwhelmingly important during a 10-year period as is generally believed.

For instance, 1939 production of lumber and wood products was predicted on the basis of 1929 input coefficients and 1939 final demands. Actual production in 1939 was less than 1 percent different from the "forecast" level. This means little in itself as such a result could have been due to pure chance or to faulty basic data, but the "predictions" for other sectors also were remarkably close and on the whole Leontief presents a convincing argument that basic structural change is a slow process.

Detailed sector data.--In connection with assembling the 1947 input-output table, the BLS made comprehensive studies of the input and output structure of several individual sectors. Some of these have been published and should prove extremely useful in many analyses of forest economic problems.

One of the most comprehensive individual sector studies concerns construction. This is summarized in three reports. The first is mimeographed and not available for general release (11); it contains the input breakdown separately for each of 16 separate construction categories. The direct material costs of each construction category in 1947 is allocated among the 190 processing industries. These data should be helpful in drawing up future bills of final demand assuming a different construction pattern than in 1947. In addition, the BLS has published two reports (12, 13) summarizing data relating to the construction sector.

Another sector publication of interest to us concerns data for sawmills and planing mills (10). These data show in detail the distribution of outputs from the sawmill and planing mill sector. The report also indicates the derivation of the figures.

Postscript

The interindustry project has recently been discontinued as an economy move. Whether or not more data will be forthcoming is highly uncertain. The Forest Service has file copies of all the publications mentioned above.

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2. Industry Reports: Manufacturing methodology, BLS Report No. 10, March 1953, 16 pp.

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